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14. ABSTRACT
This research work has established a close connection between the brain's function and the function of cooperative sociological systems. In both cases cooperation is the source of lomg-range interaction enabling the transfer of information from one subset of the system to another in spite of large Euclidean distances. This sheds light into the intelligence of a swarm and explains at the same time the surprising role that committed minorities may have to establish the consensus of a given society. It is also expected that these results may shed light into the origin of

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NETWORK THEORY OF HUMAN DECISION MAKING

ABSTRACT

This research work has established a close connection between the brain's function and the function of cooperative sociological systems. In both cases cooperation is the source of lomg-range interaction enabling the transfer of information from one subset of the system to another in spite of large Euclidean distances. This sheds light into the intelligence of a swarm and explains at the same time the surprising role that committed minorities may have to establish the consensus of a given society. It is also expected that these results may shed light into the origin of cognition.

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Fabio Vanni	0.00	
Nich Hollingshad	0.00	
FTE Equivalent:	**0.00**	
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NAME
Total Number:

Names of personnel receiving PHDs

NAME	
Malgorzata Turalska	
Nick Hollingshad	
Fabio Vanni	
Total Number:	**3**

Names of other research staff

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
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Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Technology Transfer

NETWORK THEORY OF HUMAN DECISION MAKING

This report is on the accomplishments of the Center for Nonlinear Science (CNS) on the ARO grant: Network Theory of Human Decision Making: W911NF-08-10177, in the period of time from 04/25/2008 to 12/3/2011.

The research work of these three years has established a close connection between the brain's function and the function of cooperative sociological systems. In both cases cooperation is the source of long-range interaction enabling the transfer of information from one subset of the system to another in spite of large Euclidean distances. This sheds light into the intelligence of a swarm and explains at the same time the surprising role that committed minorities may have to establish the consensus of a given society. It is also expected that these results may shed light into the origin of cognition.

(a) Transfer of information from one complex network to another.

The paper of Ref. [11] has established the foundation of a method to understand how a network with non-stationary and non-ergodic fluctuation can be stimulated by an external perturbation. The theory of Ref. [11] refers to systems whose fluctuations are renewal and non-Poisson, a condition well distinct from the combination of many Poisson processes, denoted as superstatistics [2]. The surprising result of this work is that a non-stationary and non-ergodic system is insensitive to ordinary stimuli, with a fixed time scale. The external stimulus must share the complexity of the network of interest. On the other hand, the non-ergodic nature of fluctuation is generated by criticality [1,16]. Thus, the results of Ref. [11] can be interpreted as offering the crucial prescriptions for the transfer of information from one system at criticality to another system at criticality. The work of Ref. [15] affords a detailed explanation of the main results of [11].

(b) From Psychology to Neuro-physiology

To show that the results of Ref. [11] may have important neuro-physiological applications, the Weber-Fechner law [8,9,10,22] has been used to establish the emergence of waiting time distribution densities with an inverse power law structure. At the same time the analysis of the analysis of the electroencephalogram of 30 closed-eye awake subjects was done [4] with a technique of analysis recently proposed to detect punctual events signaling rapid transitions between different metastable states. The main result of this analysis has been that the brain is confirmed to be the generator of 1/f noise, which is a manifestation of the organizational collapses emerging at criticality [17]. However, the adoption of a different method of analysis has revealed that the brain is also a coherence generator (alpha waves [5,6]). The work of [19] addressed the intriguing problem of proving that coherence and temporal complexity are not incompatible, thereby establishing a connection between the results of [4] and those of [5,6]. The main conclusion is that the brain can be interpreted as a system at criticality, generating 1/f noise. The non-invasive stimuli to produce beneficial effects on the brain function, according to [11, 21] must share the same complexity as the brain. This explains why music can be interpreted as the mirror of the brain [3]. According to [11] a complex system is insensitive to stimuli with a fixed time scale, thereby explaining the well-known phenomenon of habituation [13]. It is remarkable that according to the results of

[4] cognition is proven to be in action when the brain generates 1/f noise.

(c) Decision Making model and Sociology

The Decision Making (DM) model adopted by the West-Grigolini research group has a sociological character, being inspired to the decision making of a community of cooperatively interacting units. Each unit is linked to a set of other nodes, her nearest neighbors, and she makes a decision on the basis of the choices of her neighbors. The cooperation parameter, K, defines the cooperative effort of this unit, namely to what an extent this unit makes her decision on the basis of the choices made by the units linked to it. When this parameter becomes infinitely large this unit is totally dependent on the choices made by the units linked to it. When K vanishes, this unit makes decision on her own, with no dependence on the decision made by the other nodes. A special attention has been devoted to the case when the units are the nodes of a regular two-dimensional lattice, where each unit interacts with four nearest neighbors. When K reaches the critical value, the system reaches a consensus condition, through a form of phase transition. At the onset of phase transition, a condition called criticality, the consensus is not permanent although it lasts for a remarkable extended time. It was proved [16] that the time duration of a consensus condition is determined by an inverse power law distribution with index mu < 2. It was also proved [17] that the transition from a given decision to another is made possible by a form of organizational collapse, of very short time duration. This organizational collapse corresponds to a state where each units recovers the free-will condition that it would have in the absence of cooperative coupling with the other nodes. The organizational collapses are very beneficial for the function of a swarm of birds, because, as shown in [17], they allow the danger perceiving birds to transmit the convenient direction of motion to the whole swarm. When the DM model is used for sociological applications, and the danger perceiving birds are interpreted as a minority with unshakable opinion, the results of [17] corresponds to the finding of other investigators who have recently established that the whole community will eventually adopt the opinion of the small minority.

(d) Hebbian learning

The adoption of the DM model made it possible to prove that a set of cooperatively interacting units generates consensus by establishing long-range interaction between the units of the complex system. If the dynamically generated correlation is interpreted as a stable link, a complex scale-free network is generated, thereby implying that some unit (hubs) may play a role more important that the others [24]. This process, however, is the result of dynamics, all the units are equivalent and leadership moves in time from one to another unit. This result suggests that further studies must be done, with the assumption that correlation between two units may be converted into a stable link. The dynamically-induced scale-free distribution of links seems to be the consequence of a general principle that is emerging from the study of random walk in a network [18] showing that the scale-free distribution of links generates a fast transition of the system to equilibrium. The scale-free distribution of dynamically generated links yields a new definition of network efficiency that turns out to be more proper of the conventional definitions used so far [23].

(e) Extended Criticality

To establish a closer connection with the dynamics of neural networks, a cooperative leaky integrate and fire neural model was studied [20,25]. This model is characterized by a form of criticality [25] that is not confined to a singular value of the control parameter K, but is extended to a wide range of values. It was shown that the very popular phenomenon of neural avalanches has a cooperative origin and that phenomenon of neural entrainment has the same origin, with a close connection with the phenomenon of cooperation-induced synchronization [1]. It has to be stressed that this work shows that the cooperation between the neurons of a regular two-dimensional network generates a special form of survival probability, namely the probability that no new firing occurs till to a time t from an earlier firing. This survival probability, called Mittag-Leffler survival probability, is an important indicator of cooperation and the theoretical results of [7, 12, 14] make it possible to shed light into its physical meaning.

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